THE CELERY LEAF-TYER, PHLYCTÆNIA RUBIGALIS GUEN., IN CALIFORNIA (LEP.)

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The celery leaf-tyer, or celery worm, known also as the greenhouse leaf-tyer (2, 5, 10)[1] is a common greenhouse pest in the United States. It also attacks several outdoor crops, notably celery and sugar beets, and in California has caused serious loss to the celery industry. During its attacks on sugar beets considerable foliage is destroyed, but the actual damage is usually negligible, because the beets are usually well grown before being attacked and because ordinary feeding on the heavy foliage of the beet does not noticeably affect crop yields.

HISTORY AS AN OUTDOOR PEST

The first mention of this insect as an outdoor pest was in 1893, when G. C. Davis (4) reported it from Michigan as boring into the crown and feeding on the leaves of celery. Chittenden (2) reported numerous larvæ in a celery field in the District of Columbia in 1897, and observed the moths in a rhubarb field in 1898 and 1899. Forbes and Hart (6) reported a few adults and larvæ from a beet field in Illinois in 1900. The United States Department of Agriculture Yearbook for 1907 (9) mentions this insect as injurious to sugar beets in California, and Bethune (1) in 1909 reported it as sometimes occurring on celery in Ontario.

The first record of occurrence outdoors in California is in 1907 (9), but the first account of damage to celery was made by Quayle (7) in 1910 who writes that "it has been known to exist in Orange County for several years, but did not do serious damage until last year." Rogers (8) in 1911 writes as follows:

> "During the past season the celery fields have suffered severely from attacks of the celery leaf-tyer (*Phlyctænia ferrugalis* Hbn.). This insect has been seen in small numbers previous to this year, but had caused no large losses. This season, however, many acres of celery were almost totally destroyed by it. The worms commenced their devastations early in September and became worse up to the time the cold weather and rains set in, and from then to the last of the season they were present in most of the fields, although they were not very active."

1 Numbers in parentheses refer to "literature cited," p. 83.

Inquiries among growers and buyers of celery in the affected districts confirmed the foregoing, all agreeing that the damage became serious in 1909 and 1910, but that larvæ, moths, and scattering infestations had been observed for several seasons previously. In 1921 celery grown near the coast in Los Angeles County was severely damaged. It has in recent years become a serious celery-crop hazard in the vicinity of Sanford, Florida.

CHARACTER OF INJURY

The newly hatched larva spins a thin web, usually on the lower surface of the leaf, under which it feeds. At first only the epidermis of the leaf is eaten, but as the larva increases in size, holes are eaten through the leaves, and as feeding continues, these holes enlarge. More mature larvæ web parts of a leaf together or two contiguous leaves, in which sheltered place feeding continues. When only a few larvæ are present, slight damage is done, but if they are numerous the leaves may be skeletonized, and in severe attacks the plants are defoliated. Hence, the main injury to the celery crop in California from the leaf-tyer is the actual destruction of the foliage.

The larvæ also often make their way down into the heart of the plant, and feed on the sides of the stems, eating out irregular cavities which turn dark and are very unsightly. A large quantity of frass is left by the larvæ, which may become entangled in the web and leaves, greatly increasing the unsightliness of the celery.

Badly injured celery is unmarketable. Celery bunches with larvæ, webs, and frass in the foliage, or with the foliage a little eaten, or with the blotches on the stems, are greatly reduced in market value.

EXTENT OF DAMAGE

In the Orange County district, up to about fifteen years ago, from 5000 to 7000 acres of celery, valued at that time at over a million dollars, were raised annually. Owing to losses from the leaf-tyer and a disease, late blight,[2] this acreage began to decrease about 1911, and a sharp decline followed, until in 1916 there were less than 200 acres in the entire district. It has been estimated that one-fourth of the responsibility for this abandonment attaches itself to the celery leaf-tyer. During

[2] Septoria petroselini var. apii.

the period of greatest damage, just prior to and during the years of the rapid decline in acreage, 25 per cent of the bunches had to be discarded in many fields. Of those shipped, there was a considerable reduction in the market value on account of minor damage to the celery, or the presence of a few worms.

In the last few years a considerable acreage along the coast of Los Angeles County has been devoted to the raising of celery, maturing during the late summer and fall. This has been subject to severe damage by the leaf-tyer.

DESCRIPTION [3]

The adult is a small moth, clay brown in color, with a wing expanse of about three-fourths of an inch. The fore wings are clay brown, irregularly marked with black lines. The hind wings are gray, becoming brownish toward the ends. Both pairs of wings have a border of small black dots.

The typical position of the moth at rest is with the inner margins of the fore wings parallel and touching down the dorsum. The palpi extend rather prominently in front of the head.

The egg is broadly ovate, flattened, grayish white, but sufficiently translucent to reveal through it the color of the surface upon which it is deposited; the upper surface is shiny and iridescent. The flat, oval shape, the iridescence, and the overlapping manner in which the eggs are laid give the mass a resemblance to fish scales. As it develops, the egg turns darker, and the dark head of the embryonic larva can easily be made out through the shell. The length averages about 0.8 millimeter and the width 0.6 millimeter.

The larva when newly hatched is pale yellowish white, with a darkish head. It is about 2 millimeters long and less than half as wide. As the larva feeds, it takes on a greenish appearance. The full-grown larva is pale green or greenish yellow, and slightly translucent. Along the back there is a somewhat conspicuous green median stripe, on each side of which are double lines of white. The head is light, with faint dark spots. The surface is sparsely covered with rather long hairs. The full-grown larva is a little over three-fourths of an inch long and one-twelfth of an inch wide.

The pupa is dark, shiny brown, with conspicuous spines on the dorsum. Wing-pads and legs show plainly on the ventral side. It is slightly less than three-fourths of an inch long.

DISTRIBUTION

As an outdoor pest the celery leaf-tyer has been reported from Ontario, Canada, to Florida, and from Michigan to California and subtropical Texas. It may be found in all celery sections of southern California and is present in largest num-

[3] For complete description and synonymy, see (10).

bers and has done the greatest damage near the coast in Orange and Los Angeles counties. In the El Monte section of Los Angeles County adults may be found throughout the season, but there only occasional damage is done. It occurs in Ventura County and a few specimens have been taken at Davis, in the Sacramento Valley. Other records of occurrence as an outdoor pest are Sanford, Fla.; Baton Rouge, La.; Moreton, Delaware County Pa.; Alameda, Brownsville, Childress, and San Benito, Texas; Diamond Springs, Norfolk, and Shelton, Texas.

LIFE HISTORY IN CALIFORNIA

The moths lay their eggs on the lower surface of the leaves, or on the stems, either singly or in masses. Usually from three to eight are laid in an imbricated group, but the number may run as high as a dozen. The length of the oviposition period ranges from eight to nineteen days, averaging thirteen, and the number of eggs laid by a single female is from 48 to 176, with an average of 130.

The duration of the different stages in the life history of the celery leaf-tyer varies considerably according to the temperature, being much shorter in summer than in winter. The egg stage ranges from a minimum of four days in the summer, when the mean temperature is around 70 degrees F. to a maximum of thirty days in the winter, when the mean temperature is about 50 degrees F.; the larval stage from twenty-one to sixty-eight days. After the larva reaches maturity it ties itself up in a leaf or leaves and remains quiet for several days before turning to the pupa. This prepupal stage may last from two to ten days, and the pupal stage from six to thirty-seven days. Table 1 gives the maximum, minimum, and average number of days for each stage for the four seasons of the year, and Table 2 shows the monthly maximum, minimum, and mean temperatures for the same period. In captivity the length of the adult life was from six to thirty-four days, with an average of nineteen days.

HABITS

Soon after hatching, the young larva begins feeding on the under side of the leaves. At first only the lower epidermis is eaten, but as the larva grows it becomes more voracious and eats the entire foliage. Its leaf-tying habit soon begins to

manifest itself by the silken web with which it fastens together parts of a leaf, or two or more leaves if they happen to be in close proximity. The larva continues to feed and grow in this manner, remaining concealed in a cluster of foliage, or tied up in a single leaf. When disturbed, a larva will wriggle violently and drop down among the lower foliage or to the ground. When fully mature, the larva ties itself up tightly in a leaf or leaves, as described above, and in this protected place transforms to the pupa.

The moths begin flying about sundown, and continue to fly through the early evening. During the day they remain in hiding on the under side of a leaf or amid the foliage, and only fly when disturbed. Then they fly in a rapid, jerky manner, over the tops of the plants, and usually for a short distance only, alighting on a near-by plant, and immediately hiding under the leaves.

NUMBER OF GENERATIONS PER YEAR

From Table 1 it may be seen that during the winter the insect requires over three months to complete a generation, from oviposition to emergence of the adult; in the spring, about two months; in the summer, a little over one month; and in the fall, somewhat less than two months.

A careful check of the life-history studies carried through three seasons indicates that ordinarily there may be a maximum of five or six generations a year. Three or four of these occur during the six months from June to December, which is the active growing season for celery, and the remaining two generations occupy the balance of the year.

The generations are not entirely distinct, as there is considerable overlapping, and, while they can be observed with no great difficulty in the laboratory, they are usually too indistinct for recognition in the field.

In Table 3 is shown a continuous-generation series carried through more than a year. The first eggs from the first adults to emerge in the second and fifth generations failed to hatch, making it necessary to replace them with fertile eggs produced later. This slightly broke the continuity of the series. From eggs laid July 4, adults of the fifth generation were produced on June 18 to 23. Adding the two weeks until the end of the

year and the more than three weeks which elapsed between the second and third generations, gives ample time for the sixth generation to be produced within the year.

SEASONAL HISTORY

The main celery crop of California is practically all harvested before March 1, only a comparatively small acreage remaining later than that date. At that time the larvæ and adults are scarce, and the development of those that are present is slow.

The larvæ live on celery along drainage ditches, in the late or old abandoned fields, in old seed beds, on beets, or anywhere where their food plants are available. With warmer weather their growth and activity increase, and they will be found infesting sugar beets as well as, to a lesser degree, the celery seed beds. If a celery field is near a beet field, an infestation of the former may be expected soon after the beets are harvested, for the moths, when deprived of the shelter of the dense foliage of a mature beet field, will migrate to the celery field.

Ordinarily an infestation of any consequence occurs in the celery field about the first of September, although in some seasons it may take place as early as the middle of August. The larvæ and adults increase rapidly in numbers during September, and are very plentiful in October. By November the cooler weather, especially if there have been early rains, slows up the growth of the larvæ, and the number of both larvæ and adults becomes less. However, if warm weather continues into November, the worms will continue their activity. By December and January they will have become scarce, and only a very few can be found in February or March.

The main crop of celery is usually transplanted in July and early August and, owing to severe cutting of both top and roots, does not make much growth during the first month in the field. Hence the celery is small when infestation by the leaf-tyer begins, and the growth is very materially checked if the infestation is at all serious. Fields of excellent celery have been observed which were badly infested, and although the larvæ were finally killed by spraying, sufficient damage was done to set back harvesting more than a month.

Early planted celery usually receives the most damage, because it is exposed to infestation while the plants are small, and is ready to harvest before the larvæ have become scarce.

The later planted and marketed celery may be injured somewhat at first, but has more of a chance to recover and make a good growth, and by the time it is ready to prepare for marketing, the "worms" will have practically disappeared.

NATURAL ENEMIES [4]

Several natural enemies of the celery leaf-tyer have been taken in the field, but usually they are not present in sufficient numbers to be of any consequence in controlling the "worms." Of the internal hymenopterous parasites found, *Rhogas rufocoxalis* Cresson was the most common and *Campoplex phthorimaeæ* Cushman was occasionally taken. It is probable that at times the egg parasite *Trichogramma minutum* Riley is quite effective.

WEATHER CONDITIONS

Development is much more rapid in warm than in cold weather. A common observation among the growers, confirmed by the writer's investigation, was that larvæ were much more plentiful and damage more severe during a warm, dry season than during one when rains came early and were followed by cool fall weather.

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[4] See Chittenden (3) for a list of the parasites of this insect.

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Table I.-- Maximum, minimum, and average length, in days, of the different life stages of the celery leaf-tyer for the four seasons of the year at Alhambra, Calif.

Stage	December, January and February			March, April and May			June, July and August			September, October and November		
	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
Egg	30	14	20	20	15	17.	9	4	6	12	5	8
Larva	68	53	58	61	24	42.	27	21	23.5	44	20	29
Prepupa	10	4	5.5	4	2	3.3	3	2	2.2	4	2	3.2
Pupa	37	19	30	22	15	17	14	6	11	25	8	15.5
Egg to adult	145	90	113.5	107	56	79.3	53	33	42.7	85	35	55.7

Table 2.-- Average maximum, minimum and mean seasonal temperature at Alhambra, Calif., while the life history of the celery leaf-tyer as shown in Table 3 was being studied.

	Dec., Jan., Feb.	Mar., Apr., May	June, July, Aug.	Sept. Oct., Nov.
Ave. Max..	65° F.	68° F.	88° F.	83° F.
Ave. Min...	38	42	56	52
Ave. mean	53	55	72	67

TABLE 3.—CONTINUOUS-GENERATION SERIES OF THE CELERY LEAF-TYER

Generation	Eggs laid	Egg Stage days	Hatched	Larval stage days	Pupated	Pupal stage days	Adults emerged	Adults died	Adult stage days	Egg to adult days	Total of length of life, days
1	7-4-18	7	7-11	24	8-4	9	8-13	8-24	11	40	51
				27	7	14	21	26		48	69
2	8-17*	5	8-24	23	9-16	10	9-26			38	
		7	26	25	20	15	10-5			47	
3	10-25	6	10-31	45	12-15	30	1-14	2-14	31	81	112
	28	5	11-2	52	24	25	18	17		82	112
4	1-17-19*	14	1-31	62	4-2	17	4-19	4-25	6	99	105
		17	2-3	63	7	22	23	5-2	14	102	116
5	4-22-19*	13	5-7	30	6-7	12	6-19			55	
		14	8	31						57	
6	7-13	6	7-19	23	8-12	6	8-18	9-23	36	35	71
		7				10	22	25	34	39	73